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EFFECT OF ALUMINUM ALLOY WHEEL FORGING AND SPINNING PROCESS PARAMETERS ON FORMING FORCE

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In order to study the influence of process parameters on the forming force during the forging and spinning process of the wheel hub, five parameters were selected: die preheating temperature, blank temperature, upper die down speed, friction coefficient and feed rate.Use Deform and Simufact software to simulate and obtain the influence law of each process parameter on forming force.The results provide a certain reference for reasonable selection of process parameters in the forming process.

Keywords: aluminum alloy, forge, spin, forming force, simulation

INTRODUCTION

Currently[1], the more advanced forming methods of aluminum alloy wheels mainly include forging spinning and casting spinning. Theundergoes spinning deformation, [2] and the yield strength increases by nearly 10 %, while the spokes are still casted and still have defects such as pores and looseness.Although the cost of cast-spin-formed aluminum alloy wheels is relatively low, the coarse grains lead to poor mechanical properties.The forging and spinning process is a relatively high-end forming process in the process of producing automobile wheels. The wheels manufactured by forging and spinning are better than casting and spinning wheels in all aspects.Forging and spinning aluminum alloy wheels can not only obtain blanks closer to the shape of the wheel, but also can refine the crystal grains, weld internal micro-cracks, break the coarse phases distributed along the crystal, and improve the strength and performance of the wheel.

Kim et al. [3] of Renhe University in South Korea used the finite element (FE) method to analyze the high temperature forging process of aluminum alloy wheels, and summarized the laws of material flow, die wall pressure distribution, temperature distribution and forging load.Huang et al. [4] studied the effects of thermal spinning and heat treatment on the microstructure and mechanical properties of the A356 hub, and found that thermal spinning reduced the hardness of the hub, but greatly increased its strength.On the basis of the predecessors, this paper will analyze the influence of the forming force of the main process parameters in the forging and spinning process.

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FORGING AND SPINNING PROCESS PRINCIPLE AND FORMING FORCE ANALYSIS

The principle of forging and spinning process is shown in Figures 1 and 2. Figure 1 is the principle of forging, under strong pressure, the cylindrical blank undergoes cutting-heating-pre-forging blank-final forging forming into the initial shape of the wheel hub.Figure 2 is the principle of spinning, Through the axial and radial movement of the rotating wheel, the rotating blank undergoes local continuous plastic deformation under the rolling action of the spinning rolling, and finally obtains the required wheel hub shape.

Whether the forging work can proceed smoothly is closely related to the reasonable selection of forging equipment.The wheel hub is a large rotary forging,

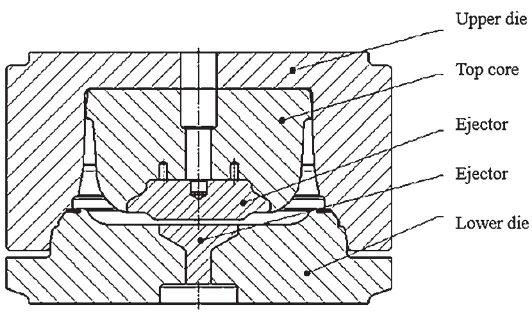

Figure 1 Principle of forging

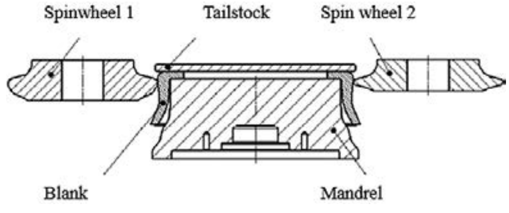

Figure 2 Principle of spinning

which requires a large forming force. If a larger tonnage equipment is selected, there will be a certain waste of resources, and the large equipment has a slow working speed, low production efficiency and high production cost. However, if equipment with a smaller tonnage is selected, the internal structure of the forging cannot be forged, resulting in coarse internal grains, and the product qualification rate cannot be guaranteed. To determine the equipment tonnage, it is necessary to calculate the pressure required by the metal during forging. Therefore, the four factors in this paper select the process parameters that have a greater influence on the forming force, which are die preheating temperature, blank temperature, forging speed, and friction coefficient. The feed rate plays a pivotal role in the spinning process [5], so this paper focuses on the influence of the feed rate on the spinning force.

MATERIAL AND FE MODEL

The automotive industry is increasingly using lightweight aluminum alloy castings to replace many parts previously made of steel and cast iron to achieve the demand for lightweight cars [6]. At present, 6061 aluminum alloy is widely used in important high-strength components in the automotive industry due to its high strength and good performance. After the aluminum alloy is formed, the various performance requirements of the wheel hub can be achieved through the subsequent heat treatment process, and it is an ideal material for manufacturing automobile wheel hubs. Therefore, 6061 aluminum alloy is selected as the material of the process. According to the existing research, the empirical constitutive equation for 6061 aluminum is as follows:

$$\varepsilon = 4{,}79\times10^{13}\left[\sinh\left(0{,}02038\sigma\right)\right]^{5{,}9659}\exp\left(\frac{-1{,}99442\times10^{5}}{RT}\right) \quad [2]$$

Where ε is is the strain rate /s^{-1}; σ_p is the peak stress; R is the gas constant (8,314 J·mol^{-1}·K^{-1}), and T is the temperature /K.

A single factor simulation experiment is designed with the preheating temperature, blank temperature , upper mold downward speed, friction coefficient as variables. The rolling process defines the following variables: preheating temperature T_1, blank temperature T_2, upper mold downward speed v, friction coefficient f. The 20 groups of single factor experiment parameters are shown in Table 1.

DISCUSSION ON THE EFFECT OF PROCESS PARAMETERS ON FORMING FORCE

Figure 3 shows that the forming force is not greatly affected by the mold preheating temperature at the beginning of the deformation. However, in the middle and late stages of the forming process, the forming force changes prominently. It can be seen from the figure that the smaller the preheating temperature, the greater the forming force. Big. For example, when the preheating temperature is 500 °C, compared with 300 °C, the forming force is reduced by 28 %. However, the preheating temperature of the mold cannot be increased indefinitely due to the limitation of the mold material. After the preheated die, when the die forging process is completed, the die surface often exceeds the preheating temperature due to heat exchange with the blank. When we select the die preheating temperature, we must consider the rise of the die temperature after forging Come in, that is, during the entire processing process, the mold temperature cannot exceed the use temperature of the material.

Table 1 **The process parameters selected in simulation**

	Reference	Change
T1 / °C	400	300 / 350 / 450 / 500
T2 / °C	300	250 / 300 / 400 / 450
v / mm s-1	10	1 / 5 / 15 / 20
f	0,1	0,1/ 0,2 / 0,4 / 0,5

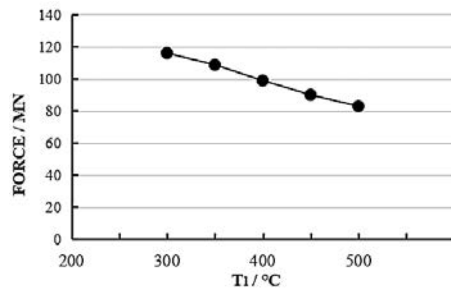

Figure 3 Effect of die preheating temperature on forging force

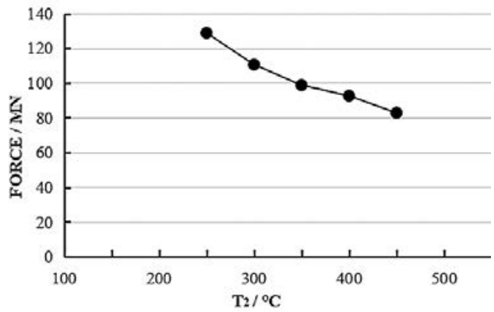

Figure 4 Effect of blank temperature on forging force

Figure 4 shows that during die forging, the higher the initial temperature of the blank, the smaller the forming force under the same die displacement.It can be seen from the figure that the forming force of the blank at 450 °C is nearly 35 % lower than that at 200 °C. Taking into account the thermal and mechanical coupling effect of the blank working, it is more reasonable to set it below 450 °C. Through simulation, we can see that the forming force is greatly affected by the temperature of the blank, and the 6061 aluminum alloy is more sensitive to the forging temperature.

Figure 5 shows that due to the fast forging speed, the heat exchange between the die and the blank is less, and the flow resistance of the blank at a higher temperature is smaller, so the forming force will decrease, but when the forming speed is quickly affected When the flow resistance is the main factor, the flow resistance will increase. Therefore, the forming force will increase rather

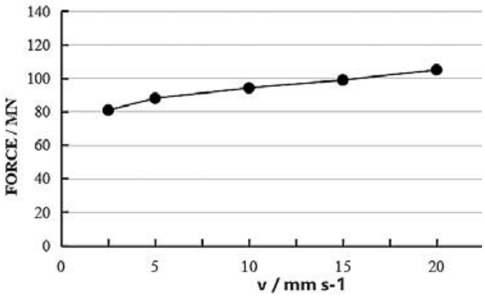

Figure 5 Effect of upper mold downward speed on forging force

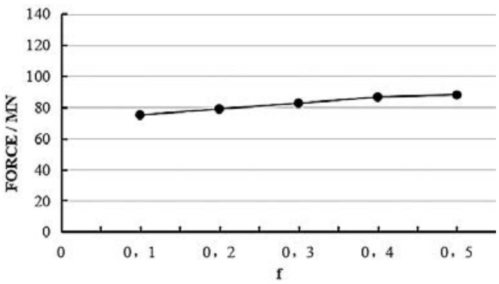

Figure 6 Effect of friction coefficient on forging force

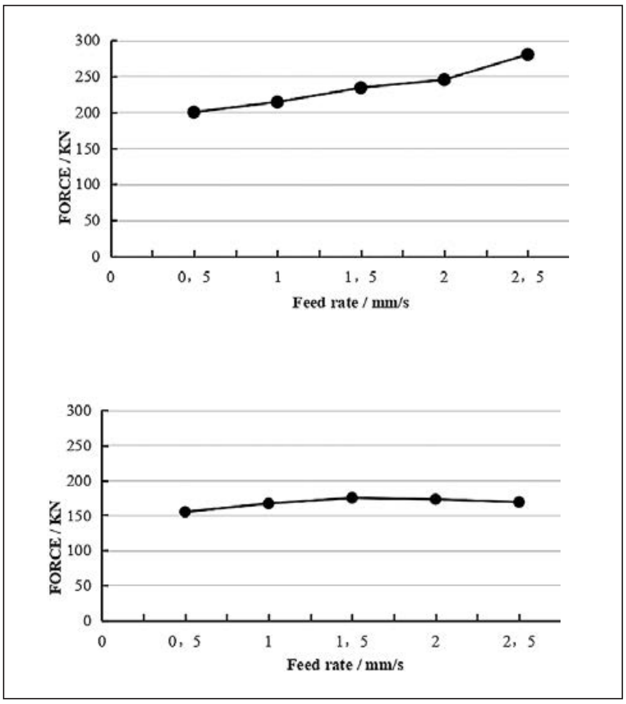

Figure 7 Effect of feed rate on spinning force
(a) X direction, (b) Z direction

than decrease. From the figure, the forging speed is 20 mm s-1 than the forging speed is 1mm s-1. The forming force is 30 % higher. Therefore, the reasonable forging speed has an important influence on the forming force, the selection of equipment tonnage, and the life of the die.

Figure 6 shows that since the contact surface between the blank and the die is less at the beginning of forging, friction is not the main factor in the forming process. Due to the deepening of the forming, the contact surface between the two gradually becomes larger. From the figure, we can see that the final forming force with a friction coefficient of 0,1 is 1 % less than that of 0,5. Therefore, in the aluminum alloy die forging process, we must choose a reasonable lubricant to reduce the forming force, thereby reducing the tonnage of the equipment, saving energy, and avoiding waste of resources.

Figure 7 shows that the spinning force in the X direction has an obvious increasing trend with the increase of the feed rate. The feed rate is 2.5 mm/s and the forming force is increased by about 40 % compared to the feed rate of 0,5 mm/s. The spinning force in the Z direction is less affected by the feed rate. In order to improve the production efficiency and the forming effect is good, we recommend that the feed rate of 1mm/s is used for spinning in actual production.

CONCLUSIONS

Reasonable process parameters can not only improve the quality of the wheel hub, but also extend the life of the equipment. During the forging and spinning process, the die preheating temperature, blank temperature, upper die down speed, friction coefficient and feed rate will all affect the forming force. This article provides scientific suggestions on how to select process parameters reasonably.

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Note: The responsible translator for English language is Y. J. Lu, Ningbo, China